DETERMINATION OF DETECTION RANGE OF MONOTONE AND CAMOUFLAGE PATTERNED FIVE-SOLDIER CREW TENTS BY GROUND OBSERVERS

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ABSTRACT

Field evaluations have determined that camouflage patterns reduce detectability ranges for uniforms and vehicles in woodland environments. This study identified the effects of three patterned and two monotoned Five-Soldier Crew Tents using detection ranges and number of false detections as determined by ground observers. The distance of correct detections were recorded along with the number of false detections. An analysis of variance for the detection ranges and number of false detections was performed. The Duncan's Multiple-Range Test was used to determine significant differences ($\alpha = 0.05$) in groups of tents. From this data, it was determined that the three patterned Five-Soldier Crew Tents were more difficult to detect than the two monotone tents.

1.0 SECTION I - INTRODUCTION

Several years ago, the U.S. Army decided that camouflage patterns have a definite advantage when used on uniforms and vehicles in woodland environments. This had led to a similar consideration for tents, since the current U.S. Army tents are solid (i.e., monotone) color. Tents present a large, relatively smooth form, making them conspicuous targets. The use of patterns to break up this signature could increase camouflage effectiveness. However, before such a judgement could be made, a field test was planned to determine the relative merits of various patterns versus monotones in a woodland background. The Natick RD&E Center fabricated three patterned tents and two monotone tents for evaluation. In consultation with Belvoir, the patterned tents were fabricated in the standard four-color uniform pattern, one in the standard pattern size and the other two in progressively larger expanded patterns. The two monotone tents were in colors Forest Green and Green 483 (483 being the textile equivalent of paint color Green 383). A test plan[1/] was developed by Belvoir at the request and funding of Natick, and the field test was conducted by Belvoir at Ft. Devens, Massachusetts, in the summer of 1987. This report describes the test and its results.

2.0 SECTION II - EXPERIMENTAL DESIGN

2.1 Test Targets

Five, Five-Soldier Crew Tents were supplied by Natick for this study in the following patterns and colors:

- Tent A - Standard size four-color uniform pattern repeated every 27.25 inches
- Tent B - Forest Green
- Tent C - Expanded four-color uniform pattern repeated every 36 inches
- Tent D - Expanded four-color uniform pattern repeated every 50 inches
- Tent E - Green 483

2.2 Test Sites

The study was conducted at the Turner Drop Zone, Ft. Devens, Massachusetts, a large cleared tract of land surrounded by a mix of coniferous and deciduous trees resembling a central European forest background. Two test sites were selected. Site #1 was located on the western end of the drop zone, so that the morning sun shone directly upon the test tent. Site #2 was located on the eastern edge of the drop zone, so that the afternoon sun shone directly upon the test tent. An observation path, starting at the opposite end of the drop zone from the test tent location, was laid out for each site. Each path followed zig-zag, random length directions toward its test site, and afforded a continuous line of sight to its respective test tent location. The paths were within a 30^{o} to 40^{o} cone from the target tents, and were surveyed and marked at approximately 50-meter intervals using random letter markers. For Site #2, the distance between markers after the first 15 markers was about 25 meters along the path. A night evaluation involving other camouflage targets led to this procedural change. The markers and distances from the tents are shown in Tables 1 and 2.

Table 1

Distances of Markers to Tents for Site #1

ALPHABET MARKER	DISTANCE IN METERS ALONG PATH FROM STARTING POINT TO TENT	ALPHABET MARKER	DISTANCE IN METERS ALONG PATH FROM STARTING POINT TO TENT
S	1,162.64	S'	464.78
Y	1,128.57	Y'	446.74
Q	1,094.00	Q'	428.17
L	1,049.93	L'	413.48
F	1,008.07	F'	398.46
P	978.31	P'	383.34
E	947.02	E'	364.64
K	902.75	K'	346.27
A	858.10	A'	334.46
T	817.81	T'	322.69
V	778.91	V'	308.59
B	750.15	B'	289.59
M	709.76	M'	281.60
U	674.87	U'	269.08
H	702.65	H'	253.16
Z	677.99	Z'	235.50
R	648.46	R'	217.81
N	613.35	N'	199.60
X	602.56	X'	178.93
I	594.57	I'	158.76
D	578.05	D'	141.15
C	561.16	C'	120.05
O	541.70	O'	102.34
J	525.33	J'	85.37
G	505.62	G'	62.81
W	483.64	W'	41.84

Table 2

Distances of Markers to Tents for Site #2

ALPHABET MARKER	DISTANCE IN METERS ALONG PATH FROM STARTING POINT TO TENT	ALPHABET MARKER	DISTANCE IN METERS ALONG PATH FROM STARTING POINT TO TENT
F	1,205.36	A	653.34
W	1,168.83	Z	613.20
U	1,130.58	E	574.09
Q	1,086.03	P	540.30
C	1,048.10	H	513.10
R	1,006.15	K	496.46
V	982.00	S	475.57
O	974.13	F '	459.10
M	942.37	W '	417.71
I	901.58	U '	379.40
B	869.75	Q '	338.25
J	858.01	C '	296.90
L	851.64	R '	278.53
X	841.26	V '	258.20
G	803.95	O '	220.73
D	764.09	I '	180.87
Y	723.46	B '	143.94
T	695.32	J '	111.00
N	673.60	L '	69.76

2.3 Test Subjects

A total of 153 enlisted soldiers from Ft. Devens served as ground observers. All personnel had at least 20/30 corrected vision and normal color perception. A minimum of 30 observers were used for each test tent, about evenly split between test sites. Each observer was used only once.

2.4 Data Generation

The test procedure was to determine the detection distances of the five tents involved by searching for them while traveling along the predetermined measured paths. Each ground observer started at the beginning of the observation path, i.e., marker S for Site #1 and marker F for Site #2. The observer rode in the back of an open 5/4-ton truck accompanied by a data collector. The truck traveled down the observation path at a very slow speed, about 3-5 mph. The observer was instructed to look for military targets in all directions except directly to his rear. When a possible target was detected, the observer informed the data collector and pointed

to the target. The truck was immediately stopped, and the data collector sighted the apparent target. If the sighting was correct, i.e., the Five-Soldier Crew Tent, the data collector recorded the alphabetical marker nearest the truck. If the detection was not correct, the false detection was recorded, and the data collector informed the observer to continue looking. The truck proceeded down the observation path. This search process was repeated until the correct target (tent) was located.

The tents were rotated between the two test sites on a daily basis, until all tents had been observed by at least 15 observers at each site. (This number of observers allows the use of parametric statistics which have a good opportunity to yield absolute conclusions). Their orientations with respect to the sun were kept constant at both test sites. The Five-Soldier Crew Tent was positioned so that a full side was facing the direction of observer approach.

3.0 SECTION III-RESULTS

3.1 Range of Detection

Tables 3, 4, and 5 show the detection data for the Five-Soldier Crew Tents. Table 3 gives the mean detection range in meters for each tent, and its associated 95 percent confidence interval. Table 4 shows the analysis of variance[2/] performed upon the data of Table 3 to determine if there were significant differences in the detection ranges, i.e., if pattern and color had an effect upon detection range. Table 5 indicates which tent patterns and solid colors differed significantly from each other in this respect. Figure 1 is a graphic display of the detection ranges of Table 3.

Table 3

Mean Detection Ranges (Meters) and 95 Percent Confidence Intervals.

TENT	N	MEAN	STANDARD ERROR	95 PERCENT CONFIDENCE INTERVAL LOWER LIMIT	95 PERCENT CONFIDENCE INTERVAL UPPER LIMIT
A	31	327.54	127.75	280.68	374.40
B	30	427.71	173.74	362.83	492.58
C	32	351.17	129.42	304.51	397.83
D	30	387.12	161.79	326.76	447.59
E	30	674.88	214.94	594.62	755.14

Table 4

Analysis of Variance for Tent Detection
Across Five Levels of Color Variation

SOURCE	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN SQUARE	F-TEST	SIG LEVEL
TENT COLOR	4	2,377,907.968	594,476.9927	22.0083	0.00*
ERROR	148	3,983,214.260	26,913.6099		
TOTAL	152	6,361,122.228			

*Significant at α less than 0.001 level.

Table 4 indicates that there are significant differences in the ability of the ground observers to detect the Five-Soldier Crew Tents in different four-color patterns and solid colors

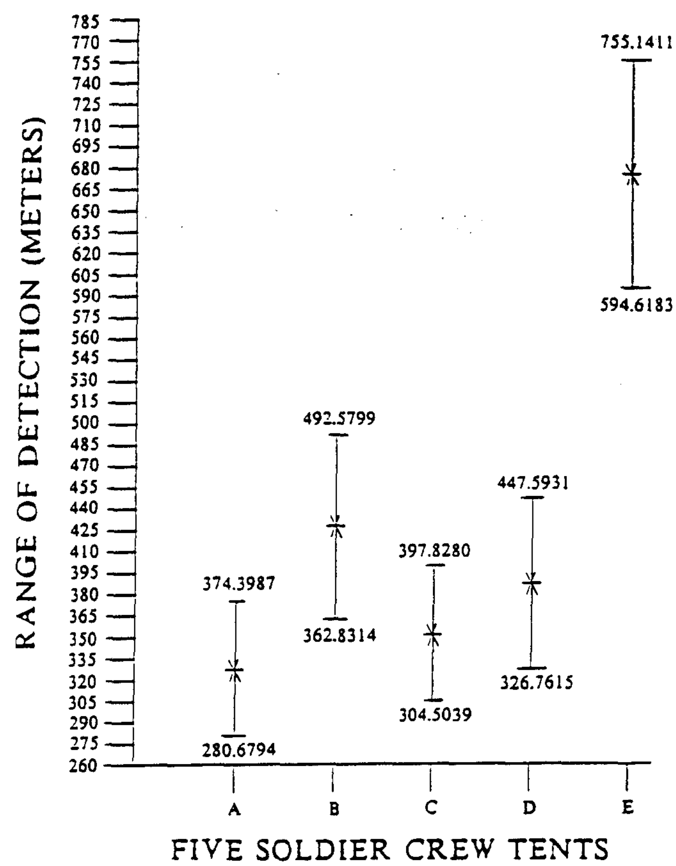

Figure 1. Mean Ranges of Detection and 95 Percent Confidence Intervals for Five-Soldier Crew Tents

Table 5

Duncan's Multiple-Range Test (Range of Detection)

SUBSET 1		SUBSET 2		SUBSET 3	
GROUP	MEAN	GROUP	MEAN	GROUP	MEAN
A	327.54	C	351.17	E	674.88
C	351.17	D	387.12		
D	387.12	B	427.71		

The harmonic mean group size is 30.58. The subsets are significant at $\alpha = 0.05$

The Duncan's Multiple-Range test separates a set of significantly different means into subsets of homogeneous means. One of the assumptions is that each random sample is of equal size. Since this was not true, the harmonic mean of the group was used as the group size. As seen above, the range of detection was the shortest for tents A, C, and D and these tents do not differ significantly from each other ($\alpha = 0.05$). Tent E had the longest mean range of detection and is significantly ($\alpha = 0.05$) different from the other 4 tents in this respect.

3.2 False Detections

The number of false detections is defined as the number of times a target other than the test target is detected by an observer. In this study such detections are rocks, trees, shadows, etc. These detections, as a rule, are a function of how hard it is to detect the test target. The more difficult the detection task, the greater the number of false detections. Tables 6, 7, and 8 show the false detection data. Table 6 gives the mean false detection value, and its associated 95 percent confidence interval, for each of the Five-Soldier Crew Tents. Table 7 contains the analysis of variance performed upon the data of Table 6 to determine if there were significant differences in the rate of false detections. Table 8 indicates which tent patterns and colors had significant rates of false detection.

Table 6

Mean False Detection Rates and 95 Percent Confidence Intervals

Tent	N	Mean	Standard Error	95 Percent Confidence Interval Lower Limit	Upper Limit
A	31	4.87	3.27	3.67	6.07
B	30	3.53	2.53	2.59	4.48
C	32	3.38	1.96	2.67	4.08
D	30	3.87	2.76	2.83	4.90
E	30	2.50	1.91	1.79	3.21

Table 7

Analysis of Variance for Rates of False
Detection across Five Levels of Color Variance

SOURCE	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN SQUARE	F-TEST	LEVEL
TENT COLOR	4	90.086	22.521	3.50	0.009
ERROR	148	953.417	6.44		
TOTAL	152	1043.503			

Significant at less than 0.01 level.

Table 7 indicates that there are significant differences in the rates of false detection for the Five-Soldier Crew Tents.

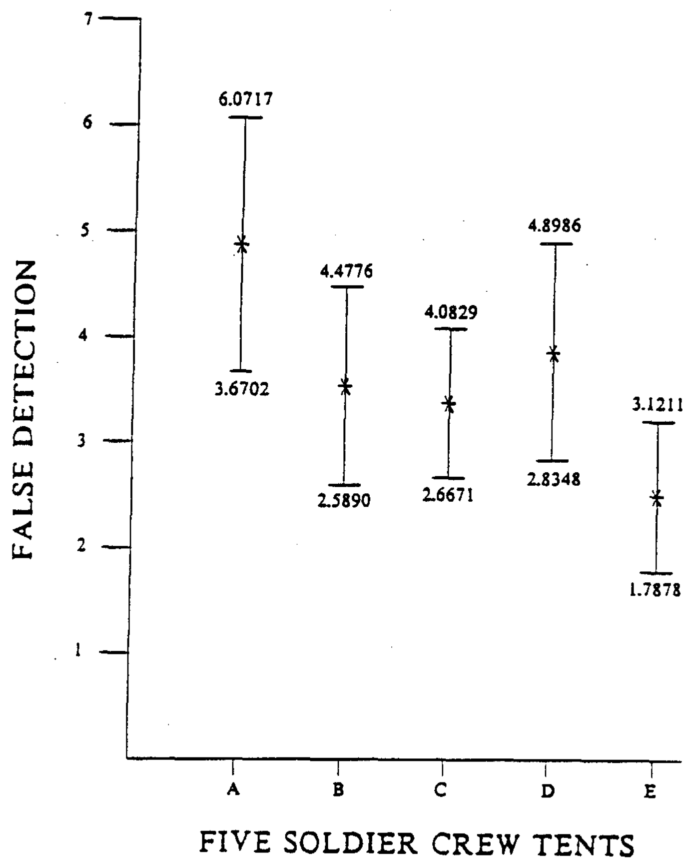

Figure 2. Mean Rates of False Detection and 95 Percent Confidence intervals For Five-Soldier Crew Tents

Table 8

Duncan's Multiple-Range Test
(Rates of False Detection)

SUBSET 1 GROUP	SUBSET 1 MEAN	SUBSET 2 GROUP	SUBSET 2 MEAN
E	2.50	B	3.53
C	3.38	D	3.87
B	3.53	A	4.87
D	3.87		

Harmonic mean group size is 30.58.

The rates of false detection for tent groups E, C, B, and D, and B, D, and A were not significantly different (α = 0.05). However subset 1 is significantly different from subset 2.

4.0 SECTION IV - DISCUSSION

The Duncan's Multiple-Range Test (Table 5) shows that the group of Five-Soldier Crew Tents A, C, and D had the shortest detection range. Tent A is the standard size woodland uniform four-color pattern, while Tents C and D are expansions of this pattern. The pattern at Tent A is repeated every 27.25 inches, the pattern for Tent C is repeated every 36 inches, and the pattern for Tent D is repeated every 50 inches. Tents C, D, and B are significantly different from each other. Tent B is solid color, Forest Green. Tent E, which is not solid color Green 483, had the longest mean detection range (674.89 meters), and this is significantly (α = 0.05) longer than any of the other means for the Five-Soldier Crew Tents. Thus, it can be concluded that the patterned tents are harder to detect from ground observation, but that the pattern should not be expanded beyond the repeat of every 36 inches. The human eye is probably resolving the larger pattern repeated every 50 inches as being different from the tree and bush background (the color brown, in particular, becomes distinguishable from the woodland background when overexpanded).

When working with detection ranges, the question of field data stability is always paramount to the amount of weight that can be given to the test conclusions. One of the best methods to determine data stability is through a test-retest procedure. Field studies are very expensive and time consuming, so this data is very rare. We do have such an opportunity to examine this type of data for the Turner Drop Zone. A ground evaluation of camouflage nets was conducted in the summers of 1985[3/] and 1987[4/]. The net sites and test procedures were identical to the sites and test procedures in which the Five-Soldier Crew Tents were evaluated. In both net studies, the standard camouflage net was evaluated. In 1985 this net had a mean detection range of 411.75 meters, while in 1987 the mean detection range was 414.41 meters. This difference in mean detection range is only 2.66 meters. From these results, it is inferred that the mean detec-

tion ranges for the Five-Soldier Crew Tents are stable, and solid conclusions about their camouflage effectiveness can be made.

The analysis of false detections seen in Table 8 and Figure 2 also lends credence to the belief that the Five-Soldier Crew Tent A had the best performance as to camouflage effectiveness, with Tent E the worst performance. In the following discussion of false detections in Section 3.2, it would be expected that Tent A, being the hardest to find, would have the most false detections, and Tent E the least number of false detections. This is exactly what occurred, with Tent A having a mean false detection rate of 4.87, and Tent E a mean false detection rate of 2.50. Duncan's Multiple-Range Test (Table 8) shows that the two rates of false detection differ significantly ($\alpha = 0.05$) from each other. The false detection rates of tents B, C, and D are not in the expected ordinal position. The expected order, based upon mean range of detection, would be B, D, and C, while the true order of rates of false detection is C, B, and D. However, a check of Tables 5 and 8 shows that these tents are not significantly different from each other either for range of detection or for rate of false detection. Thus, from a statistical view, these three tents are considered to have the same ordinal position.

5.0 SECTION V-SUMMARY AND CONCLUSIONS

Five, Five-Soldier Crew Tents were evaluated by ground observers to determine their camouflage effectiveness as measured by the mean detection range and the mean rate of false detection. These tents were in the following four-color camouflage patterns and solid colors:

- Tent A - Standard size four-color uniform pattern repeated every 27.25 inches.
- Tent B - Forest Green
- Tent C - Expanded four-color uniform pattern repeated every 36 inches
- Tent D - Expanded four-color uniform pattern repeated every 50 inches
- Tent E - Green 483

A minimum of 30 ground observers per Five-Soldier Crew Tent were driven toward each of two sites on marked observation trails in the back of an open 5/4-ton truck. The observers were looking for military targets, and they informed the data collector when they thought they saw one. If the detection was correct, the closest alphabetic ground marker to the truck was recorded. From this letter, the distance to the tent from the truck was determined. If the detection was not correct, i.e., false detection, it was noted on the data sheet. The ground observer then continued the search, with the truck traveling down the observation path until the test target was seen. An analysis of the resulting data provided the following conclusions:

A. Five-Soldier Crew Tent A was the most camouflage effective, with the lowest mean range of detection and highest rate of false detections.

B. Four-color pattern Five-Soldier Crew Tents are more camouflage effective than solid colors.

C. The expanded four-color pattern, repeated every 50 inches, is too large to be effective in denying detection. (The color brown becomes distinguishable from the woodland background when overexpanded).

D. The solid colors Green 483 and standard Forest Green should not be used.

E. The mean range of detection data appears to be very stable. A test-retest field study using identical sites and test procedures in the summers of 1985 and 1987 involving the standard camouflage net yielded mean detection ranges of 411.75 and 414.41 meters respectively.

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